Benefits from Micro and Secondary Nutrients: Impacts on Farm Income and Livelihoods in Rainfed Tribal and Backward Regions of Andhra Pradesh

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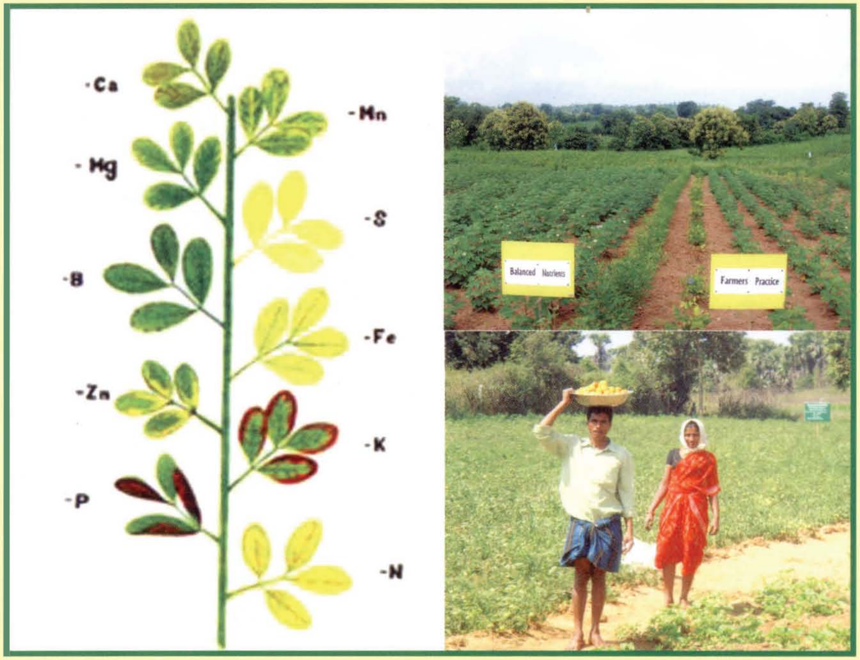

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Patancheru, Medak district, 502 324, Andhra Pradesh, India

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Dr. A.K. Singh
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Foreword

In India, rainfed cropping is practiced on 80 Mha, in arid, semi-arid and sub-humid climatic zones; constituting about 57% of the net cultivated area. Even after development of all irrigation water resources, around 50% of the cultivated land will remain rainfed. Low and erratic rainfall, high temperature, degraded soils with low available water holding capacity and multinutrient deficiencies, low input use and low use efficiencies of applied nutrients, are important factors that contribute to low crop yields in these regions. Besides major nutrient deficiencies, deficiency of secondary and micro nutrients has also crept extensively in rainfed regions as supplementation of nutrients is seldom practiced. Additionally, adoption of intensive cereal based cropping systems, imbalanced use of fertilizers largely due to subsidized urea and DAP, micro and secondary nutrient deficiencies have become limiting factors for realizing potential yields. Among these, sulphur (S), boron (B) and zinc (Zn) are considered to be the most limiting nutrients in the rainfed areas, even in intensively cultivated tribal and backward regions. Judicious and balanced or integrated use of nutrients based on Site Specific Nutrient Management (SSNM), will play a major role in improving nutrient use efficiency, achieving food security and solve malnutrition problem in rainfed regions.

The authors have done a commendable job of highlighting the extent of secondary and micronutrient deficiencies at state level covering clusters of rainfed backward and tribal regions, depicting deficiency symptoms of different crops, recommendations for different rainfed crops and cropping systems, yield and economic advantages of micro and secondary nutrient application as well as farmers' opinions. I trust that this bulletin prove to be informative and handy from a practical point of view as well as be useful to researchers, planners and policy makers in ensuring agricultural sustainability under different rainfed cropping situations in backward areas. In fact, this publication paves the way to promote balanced use of fertilizer for higher yields, thus improving farmers' profit by breaking the barriers of stagnating/declining trend in the crop productivity in the rainfed regions of the country which were bypassed by the green revolution of the sixties and seventies.

(A.K. Singh)

New Delhi
September, 2011

Plants require 16 nutrients for proper growth and development. Nitrogen (N), phosphorus (P), and potassium (K), are needed in large quantities (macronutrients). Others, such as calcium (Ca), magnesium (Mg) and sulfur (S), are required in small quantities (secondary nutrients). Plant nutrients, like zinc (Zn), boron (B), manganese (Mn), iron (Fe), copper (Cu), molybdenum (Mo) and chlorine (Cl), are required in very small quantities (micronutrients). In rainfed regions of the country, declining soil fertility and nutrient imbalances are major issues affecting agricultural productivity (Srinivasarao 2011a). Organic matter levels have declined sharply in intensively cropped regions, leading to stagnant yields of major food crops in India. In addition to universal deficiency of nitrogen, deficiencies of potassium, sulphur and micro nutrients are emerging as constraints for sustaining and or enhancing productivity under intensive crop production systems. Zinc, sulphur and boron deficiencies are widespread across the vast dryland tracts of India (Srinivasarao et al. 2008a, c). It is estimated that 29.4 m ha of soils in India are experiencing decline in fertility with a net negative balance of 8-10 m t of nutrients per annum. Poor nutrient use efficiency is another cause of concern. So far soil fertility issues have been addressed mainly in irrigated agriculture, but recent studies indicated that drylands are not only thrusty but also hungry. Most of the soils in the rainfed regions are low in organic carbon and available N, and these soils are showing multi-nutrient deficiencies including secondary and micronutrients also.

Soil organic matter, being the storehouse of many plant nutrients has a significant effect on productivity besides improving water retention and soil microbial diversity. However, due to competing usages of organic resources, application of organic manure and crop residues has declined over time. Considering the growing nutrient imbalance in soils and crop plants, even if we use all organic manures available in the country, we will still have a large deficit of essential plant nutrients (Srinivasarao et al. 2009a). Use of chemical nutrients to some extent therefore, is inevitable to sustain agricultural productivity and food security of the country.

Fertilizers contribute about 50% of the increased yields as a component of improved technology. The dramatic increases in the yields of crops like wheat and rice have occurred because of high yielding varieties and higher fertilizer use. The yield potential of many dry land crops has not been tapped much despite the introduction of high yielding cultivars because of low nutrient use. About 80% of the fertilizer is consumed in irrigated areas while only 20% is used in the rainfed areas that constitute 65% of the cropped area. Hence, apart from several other reasons, low nutrient use in rainfed agriculture is one of the important causes of low yields (Srinivasarao et al. 2006, 2011b). Efforts therefore need to be made to redefine the fertilizer doses by synchronizing with the crop nutrient demand water availability in the soil particularly in drylands.

Problem

Imbalanced use of high analysis chemical fertilizers mainly N and P combined with the declining use of organic sources of nutrients over time, has led to the deficiency of micronutrients in soils, resulting in poor soil fertility (Srinivasarao et al. 2006, 2008b). Nutrients such as sulphur, magnesium, zinc, iron, boron, and manganese,

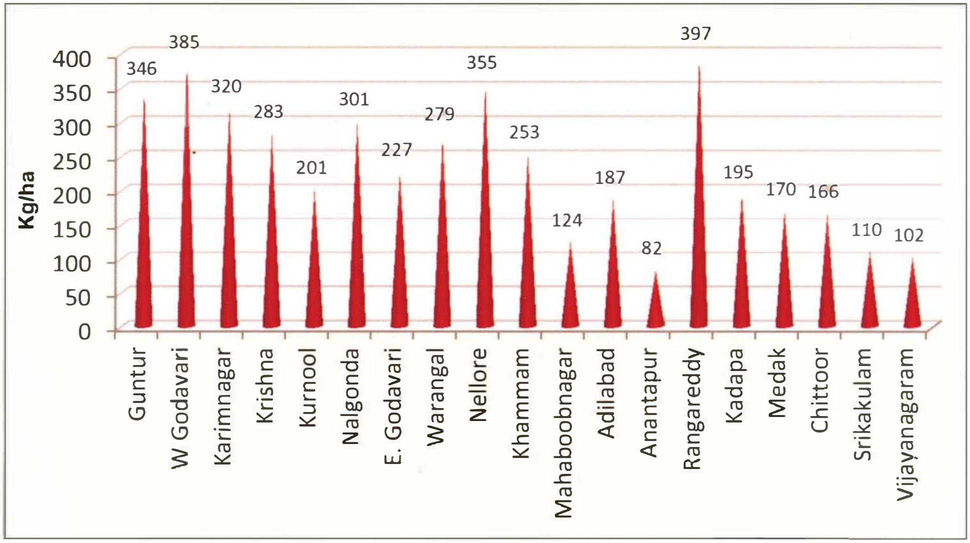


Figure 1. Application of macro nutrients in different districts of Andhra Pradesh ($N + P_2O_5 + K_2O$)

copper are equally important to plant growth as N, P and K. When these micronutrients are not available to the plant in required quantities, growth is affected and yields are reduced. Present day nutrient application scenario in Andhra Pradesh shows the use of large amounts of major nutrients (NPK) to the extent of 397 kg ha^{-1} in Rangareddy district. Among the various districts of Andhra Pradesh, NPK application varied from 82 kg ha^{-1} in Anantapur to 397 kg ha^{-1} in Rangareddy district (Fig. 1). However, application of micronutrients such as zinc, iron and boron is rather rare. Similarly, many oil seed and pulse crops require higher amounts of sulphur, but S is not applied even in S-deficient soils (Srinivasarao et al. 2011 c, d). Cotton crop often suffers from magnesium deficiency, resulting leaf reddening particularly in light - textured red soils of Andhra Pradesh. Most of the soils in Andhra Pradesh are zinc deficient and iron is deficient in calcareous soils (Srinivasarao and Vittal 2007). Many crops like groundnut, maize, fruit crops and vegetables are affected by B deficiency.

Target Area

The target area for this study comprised of eight rainfed backward and tribal dominated districts of Andhra Pradesh covered under the Component 3 sub project "Sustainable rural livelihoods through enhanced farming systems productivity and efficient support systems in rainfed areas" under NAIP, which is being implemented by a consortium led by the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad since September 2007 (Fig. 2). It aims at improving the livelihoods of the rural poor by improving the overall systems productivity by following good agricultural practices, better natural resource management and addressing

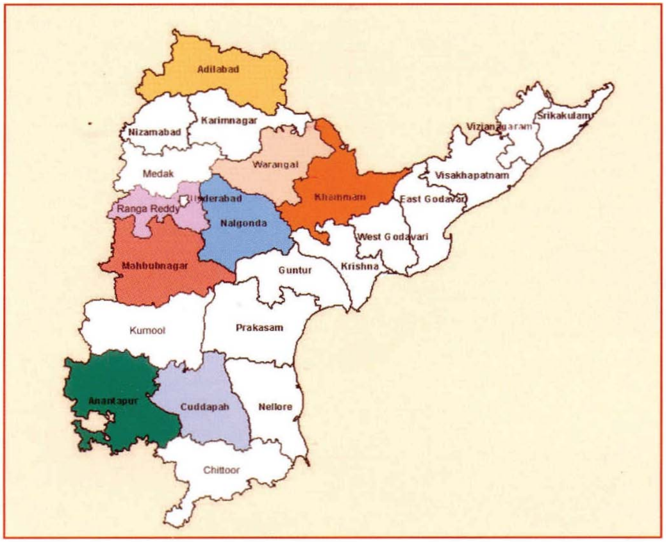


Figure 2. Target districts where 84 villages were identified for demonstrations

the issues of profitability and sustainability through efficient institutional and support systems. The project sites are selected based on the criteria of dominance of rainfed farming, SC and ST population, low household income and poor infrastructure. General description of the study sites are given in Table 1.

Table 1. Details of study sites/villages selected in the target districts

District	Villages	No of villages	No. of Households	Area (ha)	Characteristics of the cluster	Soil Type	Crops
Adilabad	Seethagondi, Garkampet, Arkapally, Old Somwarpet, Pedamalkapur, Chinamalkapur, Kotwalguda, New Somwarpet	8+2*	575	1296	High tribal population (70%) and close to forests, very low productivity and technology adoption. VSS are active.	Black	Cotton Pigeonpea Chickpea Vegetables
Nalgonda	New banjara hills, Jamal kunta thanda, Seetamma thanda, Yellapa kunta thanda, Chinagore kunta thanda, Pedagore kunta thanda, Peda seetharam thanda, China Seetharam thanda, Lalsingh thanda	9+9	621	500	Highly drought prone area, off season employment and high migration rates, small hamlets/ tandas with more than 80% tribes.	Red	Groundnut Pigeonpea Greengram Sorghum Vegetables Horticulture crops

District	Villages	No of villages	No. of House-holds	Area (ha)	Characteristics of the cluster	Soil Type	Crops
Khammam	Bheemavaram, Koremvarigumpu, Kurvapally Kothuru, Mamillavai, Ramavaram, Thummalacheruvu Venkatapuram	7+4	650	1000	High tribal population assigned and forest lands, poor communication and market facilities, and high indebtedness.	Red and black	Cotton, Sorghum Maize
Mahabub Nagar	Zamistapur Telugugudem Kodur Thanda	3+4	734	756	Highly drought prone area, more landless families, degraded lands, high livestock population, fodder scarcity, high migration and, limited livelihood opportunities.	Red and black	Castor, Sorghum, Groundnut
Anantapur	Pampanoor, Pampanoor Thanda, Yennamkothapally	4+4	576	1430	Most drought prone area, extensive monocropping of groundnut, re-peated crop failures and water shortages, limited livelihood opportunities.	Red (gravelly)	Groundnut
Kadapa	B.Yerragudi, Kapu Palli, BA. Nagireddy Palli, Madhiga Palli, Moodindla Palli, Puttakarla Palli, Puttakarla Palli Colony, Konampeta	8+5	216	1060	Drought prone area with predominance of small and marginal farmers with maximum erodable lands. Lacks proper credit and agricultural market facilities.	Red and black	Groundnut Sunflower Vegetables
Warangal	Jaffer gudem, Kusumbai Thanda and Satynarayana Puram, Jal Thanda, Ramanna Gudem, Vepala-gadda thanda, Cherla thanda, Lokya thanda	7+3	689	2070	Village with high tribal population, degraded soils with good potential for water harvesting and drought proofing measures.	Red and black	Cotton Rice Pigeonpea
Ranga Reddy	Ibrahimpur, Dhadi Thanda, Roopsing Thanda, Malkaypet Thanda	4+3	409	346	Village with high migration rates and lack of irrigation facility, more forest land, high use of chemical inputs and indebtedness.	Red sandy	Maize Pigeonpea Vegetables

*Extended villages

Field scale nutrient deficiency in different crops grown in target districts

During PRA and visits to farmers fields several nutrient deficiencies have been observed in field crops. Among micronutrients, Zn deficiency was observed in cotton, maize, chickpea, fruit crops (orange and water meleon), Fe deficiency in chickpea, groundnut, maize, B deficiency in groundnut, tomato, maize, cotton and several fruit crops, Ca deficiency in mango orchards, Mg in cotton, S in maize sunflower and cotton (Fig. 3 to 7). The field level nutrient deficiency symptoms in various crops given below will help farmers and field workers in the identification of nutrient deficiencies in various crops grown in the target regions.

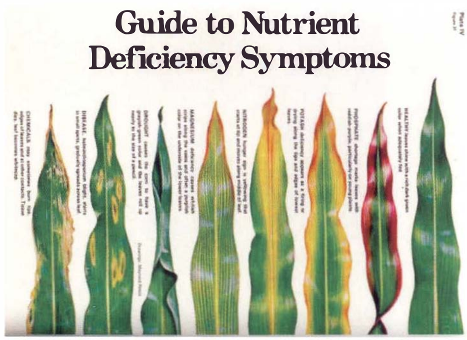


Figure 3. Guide to identify nutrient deficiency in the field crops

Figure 4.Magnesium deficiency in light textured red soils (Large scale reddening in cotton in long view) of Warangal and Khammam districts

Figure 5. Sulphur deficiency in B. Yerragudi (Kadapa) and maize in Parigi cluster (Ragareddy district)

Figure 6. Zinc and iron deficiencies in citrus seedlings in Dupahad cluster in Nalgonda district (left) and Fe deficiency in groundnut in Pampanur cluster in Anantapur district

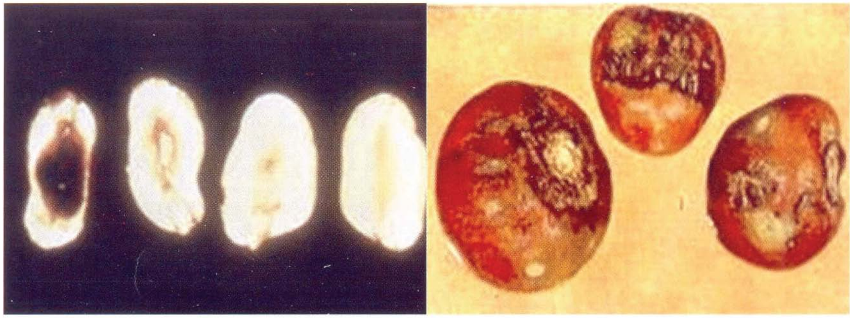


Figure 7. Boron deficiency found in groundnut (Pampanur and B. Yerragudi) and tomato in Dupahad (Nalgonda) clusters

How the problem was addressed?

Participatory Soil Sampling

With several interactions, meetings with farmers in these villages, farmers were sensitized to go for soil testing. Soil samples from 1850 farmers' fields covering 84 villages of the eight districts were collected during 2007-2011 with farmer participation in soil sampling (Fig. 8). After conducting farmers' meeting in each village and depending upon soil type, crop, slope and management, about 30 per cent of farmers' fields were selected for sampling using stratified random sampling methodology. The identified farmers were made into groups for demonstration of soil sampling procedure. Collected soil samples were labeled with cluster, village and farmer's names. In most of the clusters, village sarpanch or village head was involved in participatory soil sampling. Collected soil samples were analyzed in the soil chemistry laboratory at the CRIDA.

Figure 8. Participatory soil sampling in the farmers' fields and chemical analysis at CRIDA Soils Laboratory

Nutrient deficiencies in target districts

Adilabad: Soils of Adilabad cluster are neutral to alkaline in reaction. EC is normal. 27% of farmers' fields are low in organic carbon, 63% fields are deficient in available N, 60% in available P. Among micro and secondary nutrients S, B and Zn were found mostly deficient to the extent of 32-76% of farmers' fields (Table 2) (Srinivasarao et al. 2010a, b).

Nalgonda: Soils are mostly slightly acidic to alkaline. There are no salinity problems, except in a few fields. Sixty eight per cent of the sampled fields are low in organic carbon. Among major nutrients N and P deficiency are very common to the extent of 76 and 29%, respectively. Sulphur, B and Zn deficiencies are to the extent of 61 and 51%, respectively. Four and 9% fields were deficient in available Fe and Cu respectively.

Khammam: Soils are acidic to alkaline in pH. There is no salinity problem. Twenty five per cent of the fields are low in organic carbon. Sixty per cent of the fields are deficient in N and P and 67% in S, 37% in B and 45% in Zn.

Mahaboobnagar: Soils are slightly acidic to alkaline in reaction. Selected fields have salinity problem. Sixty two per cent fields are low in organic carbon (Table 2). N, P and K deficiencies were 66%, 43% and 18%, respectively. Fifty three per cent are critically deficient in S, 43% in B and 48% Zn respectively.

Kadapa: Soils are highly degraded, light - textured and acidic to alkaline in pH. Some of the fields have salinity problem (Table 2). Ninety six per cent fields are low in organic carbon. N, P and K deficiencies are to the extent of 61, 84 and 54%, respectively. Similarly, S, B and Zn deficiencies are widespread to the extent of 79, 65 and 85%, respectively.

Anantapur: Soils are acidic to alkaline (Table 2). Some of the fields have salinity problem. Sixty six as fields are low in organic carbon. N and P deficiencies were to the extent of 61 and 32%, respectively. More than 50 per cent of the farmer's fields are found deficient for S, B and Zn (Table 2).

Warangal: Soils are neutral to alkaline (Table 2). Some of the fields have salinity problem. Eighty one per cent fields are low in organic carbon, 61% are deficient in N and only 14% fields are found deficient in P. Similarly, S, B and Zn deficiencies are observed to the extent of 77, 44 and 50% respectively.

Rangareddy: Soils are acidic to alkaline in reaction (Table 2). Some of the fields have salinity problem in patches. Fifty five per cent fields are low in organic carbon. Nitrogen, P and K deficiencies are to the extent of 61, 39 and 17%, respectively. Sulphur, B and Zn deficiencies are observed to the extent of 68, 54 and 35%, respectively.

Table 2. Cluster-wise fertility status in farmer's fields of (1850) rainfed tribal districts of Andhra Pradesh (2007-2011) (values for each district in a column represent mean, range, and percentage of deficient fields)

Name of the District		pH	EC (dS/m)	OC (%)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Av S (kg/ha)	Av.Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Av. B (mg/kg)
Adilabad (139)*	Range	6.2-8.8	0.08-2.66	0.27-1.33	122-355	6-109.3	46-549	2.0-142.2	0.22-2.90	0.86-11.42	0.56-1.70	1.44-22.1	0.10-0.74
	Mean	8.1	0.29	0.62	210	15.5	205	12.2	0.62	5.59	1.1	6.89	0.34
	% deficient farmers' field			27	63	60	2	76	74	3	3	-	32
Nalgonda (420)	Range	5.3-8.8	0.07-1.60	0.14-1.13	136-297	0.2-50.4	21-346	2.1-140.3	0.22-6.58	0.96-12.52	0.47-1.60	1.47-20.30	0.04-1.20
	Mean	7.4	0.29	0.46	192	9.0	89	17.0	1.02	5.76	1.01	6.50	0.34
	% deficient farmers' field			68	76	29	14	61	51	4	9	2	36
Khammam (161)	Range	4.8-8.6	0.03-0.82	0.32-1.50	157-343	0.2-57.8	31-856	3.6-71.9	0.28-6.80	0.89-10.52	0.59-1.81	1.59-24.33	0.12-1.22
	Mean	6.7	0.18	0.70	204	8.5	180	10.6	1.09	5.01	1.19	7.30	0.39
	% deficient farmers' field			25	61	60	2	67	45	3	6	2	37
Mahabub nagar (232)	Range	6.0-10.2	0.01-2.37	0.13-1.13	108-367	0.2-44.4	25-1263	3.4-287.3	0.30-4.68	0.81-12.78	0.52-1.76	1.49-22.43	0.04-1.24
	Mean	7.80	0.22	0.44	179	8.7	105	11.6	0.96	4.66	1.22	6.32	0.36
	% deficient farmers' field			62	66	43	18	53	48	3	5	2	43
Anantapur (256)	Range	5.5-8.8	0.02-3.20	0.12-1.45	128-358	0.6-42.4	38-1488	3.5-117.3	0.26-5.00	0.99-11.10	0.69-1.71	1.46-20.13	0.06-1.40
	Mean	7.4	0.18	0.45	174	8.4	116	10.0	0.88	5.36	1.19	5.34	0.32
	% deficient farmers' field			66	61	32	9	55	61	3	6	3	62

Name of the District		pH	EC (dS/m)	OC (%)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Av S (kg/ha)	Av.Zn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Av. B (mg/kg)
Kadapa (158)	Range	6.0-8.8	0.02-1.30	0.12-1.31	63-390	0.2-13.4	17-482	1.8-222.6	0.24-5.20	0.82-13.16	0.68-1.71	1.47-19.31	0.04-1.46
	Mean	7.3	0.12	0.26	125	2.5	61	6.6	0.61	5.09	1.26	6.30	0.16
	% deficient farmers' field			96	61	84	54	98	78	4	5	2	65
Warangal (279)	Range	6.1-9.4	0.04-1.68	0.08-0.84	76-426	0.2-53.4	21-280	1.8-48.9	0.26-3.88	0.84-11.26	0.69-1.54	1.64-21.33	0.10-1.42
	Mean	7.8	0.27	0.41	190	16.0	118	9.4	0.96	5.32	1.25	6.24	0.38
	% deficient farmers' field			81	64	14	5	77	50	4	4	3	44
Ranga Reddy (205)	Range	4.7-8.2	0.02-1.16	0.15-1.56	88-338	0.2-60.0	24-405	1.1-81.6	0.30-8.00	0.94-9.52	0.69-1.66	1.48-18.33	0.06-1.24
	Mean	6.7	0.12	0.50	215	8.9	92	3.7	1.22	4.89	1.05	5.32	0.26
	% deficient farmers' field			55	61	39	17	69	35	3	7	3	54

Critical limits considered for low content : OC<0.5%, Av. N<280 kg ha^{-1}, Av. P<12 kg ha^{-1}, Av. K<120 kg ha^{-1}, Av. S<22.4 kg ha^{-1}, Zn<0.75 mg kg^{-1}, Cu<0.5 mg kg^{-1}, Fe<6 mg kg^{-1}, Mn<1.0 mg kg^{-1}, B<0.58 mg kg^{-1}

The Strategy

During 2007-10, a total of 265 on-farm trials were conducted with different test crops in Adilabad (*kharif* cotton and *rabi* chickpea), Khammam (cotton), Warangal (cotton), Anantapur and Kadapa (groundnut), Mahabubnagar (cotton, castor and rabi groundnut), Rangareddy (maize and pigeonpea) and in Nalgonda (groundnut, green gram, black gram and vegetable crops like tomato and Bhendi) districts with the objective to demonstrate the comparative evaluation of SSNM including micro and secondary nutrients and farmers practice. Crops were grown on selected farmers' fields with known fertility status and SSNM based nutrient application (Table 3).

Some of the villages in the districts (Warangal, Adilabad, Nalgonda, Khammam and Rangareddy) P build up in the soils was determined. In these farmer's fields, P dose was reduced to half. K application was introduced. However, K deficient fields were found in all the districts and K fertilizer was introduced in these fields. Similarly sulphur, zinc and boron were applied depending upon soil test data (Table 3). SSNM package for individual farmers' field was developed based on crop grown and soil test data. Nitrogen in invariably low in all the villages and recommended N was used for the crops.

Figure 9. Organizing Gram Sabha and discussions on soil test data with farmers and field visits on proposed interventions

Micronutrients in SSNM were compared with the farmers' practice in an area of half acre in each of the farmers' fields. The balanced nutrition included a recommended dose of fertilizers (90 kg N and 50 kg P_2O_5 for cotton, 20 kg N and 40 kg P_2O_5 for chickpea, groundnut and green gram, 150 kg N and 80 kg P_2O_5 for tomato and 120 kg N and 60 kg P_2O_5 for Bhendi) along with basal application of micro-nutrient mixture of 2.5 kg agribor/5 kg borax (0.5 kg B ha^{-1}), 50 kg zinc sulphate (10 kg Zn ha^{-1}) and 200 kg gypsum/elemental sulphur (30 kg S ha^{-1}) per hectare (Fig.10). K was introduced in K deficient fields. Farmer's practice in each trial was documented, which included suboptimal dose of N and P. Entire dose of N and P was applied as basal. Besides other crop management practices like weeding and pest and disease control measures were followed.

This is first among a few studies on taking the SSNM and INM approaches into field adaptation and relating soil health with productivity and livelihoods of rural poor with eight consortium partners.

Development of micro and secondary nutrient based fertilizer recommendations

Soil test data and deficiency of various nutrients in each farmer field tested was discussed with farmers and Department of Agriculture, line department experts and in the farmers meeting and field visits. Based on soil test data and crop grown in each field, nutrient recommendations sheet was developed each farmers

Figure 10. Preparing micronutrient mixture and incorporating micronutrients into the soil

field. Site Specific Nutrient Management (SSNM) sheet developed for groundnut and greengram field in light textured red soils at Dupahad cluster of Nalgonda district is presented in Table 3.

Table 3. Farmer field specific fertilizer recommendation developed for oilseed/pulse crop (viz. Groundnut and greengram) based on soil test value for Dupahad cluster of Nalgonda district, AP

Farmer No.	Village	Crop	Fertilizer requirement (kg ha-1)				
			Urea	DAP	MOP	Gypsum	$ZnSO_4$
1	Jalmakunta tanda	Greengram	50		90		
2	Jalmakunta tanda	Groundnut		125	90		50
3	New Banjarahills	Greengram	50		65	150	50
4	Jalmakunta tanda	Greengram	50				25
5	Jalmakunta tanda	Greengram		125	90	150	50
6	Seetamma tanda	Groundnut	50		90		50
7	Jalmakunta tanda	Greengram	50				50
8	New Banjarahills	Greengram		125	65	150	50

Farmer No.	Village	Crop	Fertilizer requirement (kg ha-1)				
			Urea	DAP	MOP	Gypsum	$ZnSO_4$
9	Peddagarakunta tanda	Greengram	50		90	150	50
10	Jalmakunta tanda	Greengram		125			50
11	Jalmakunta tanda	Greengram		125	90		50
12	Jalmakunta tanda	Greengram	50		65		50
13	Jalmakunta tanda	Green gram		125	90	150	50
14	Jalmakunta tanda	Green gram		125	65	150	50
15	Jalmakunta tanda	Green gram		125	65	150	50
16	Jalmakunta tanda	Green gram		125	65		25
17	Jalmakunta tanda	Green gram	50		65		50
18	Jalmakunta tanda	Green gram	50		90		50
19	Jalmakunta tanda	Bhendi		125	90		50
20	Peddagarakunta tanda	Green gram	50		65		25

Benefits to Farmers

- **Adilabad:** In Adilabad district, the benefits of balanced nutrition were much higher. This could be due to continuous cotton-based system with a mean yield of 2.37 t ha^{-1} of seed cotton (SSNM) compared to mean yield of 1.66 t ha^{-1} in FP, registering 43.1% yield increase (Fig. 11). Low levels of fertilizer application to cotton, chickpea or cotton-pigeonpea intercropping system over the years resulted in mining of soil nutrients. Though, these villages are with 100 per cent tribal population, the cotton is grown for the last 10-15 years without much nutrient inputs (Fig. 13). This is one of the reasons for higher cotton response to balanced nutrition. Among the *rabi* crops, chickpea (variety JG-11) showed significant response to SSNM in Seethagondi cluster of Adilabad district. Mean seed yield increased from 0.89 to 1.21 t ha^{-1} due to balanced nutrition, registering 35.1% yield increase. Being a pulse crop, its S requirement is met from added sulphur in the form of gypsum besides application of other nutrients. However, the variation in the crop response to balanced nutrition was wide among farmers' fields. The improvement in chickpea yield with balanced nutrition varied from 15 to 58% over farmer's practice. This indicates that with improved varieties of chickpea (JG-11), a well nourished crop can yield up to 1.5 t ha^{-1} on deep black soils of Adilabad district.
- **Khammam:** Soils in Tummalacheruvu cluster in Khammam district are fine textured red soils with multi-nutrient deficiencies (Fig.13). Cotton yields (Bt) ranged from 0.9 to 2.5 t ha^{-1} in farmers' practice with an average yield of 1.9 t ha^{-1} and yield levels improved in the range of 1.3 to 3.2 t ha^{-1} in SSNM with an average yield of 2.4 t ha^{-1}, showing 13.6-53.0% increase in yield. These results were in accordance with earlier reports in other dryland regions of India (Srinivasarao et al. 2008c)

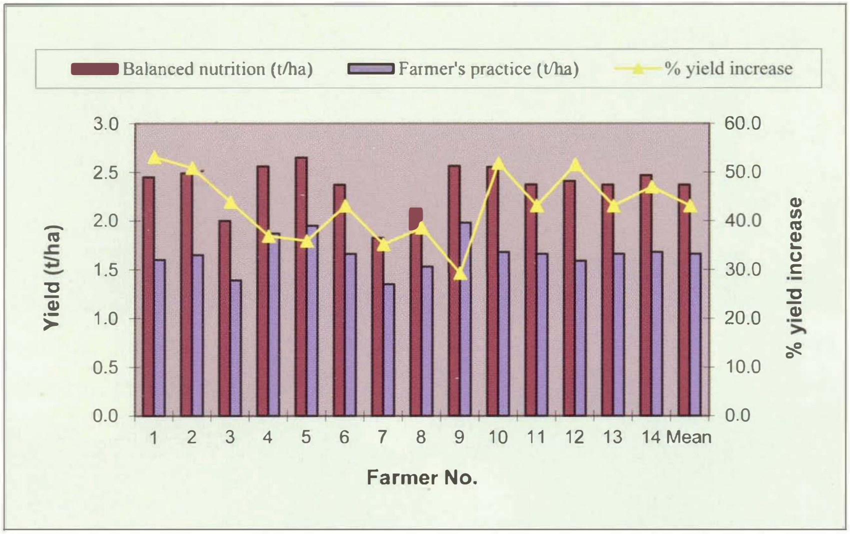


Figure 11. Effects of balanced fertilization on cotton yield in farmers' fields of Seethagondi cluster, Adilabad district, Andhra Pradesh, *Kharif* 2009-2010. (CD (P=0.05) 0.19).

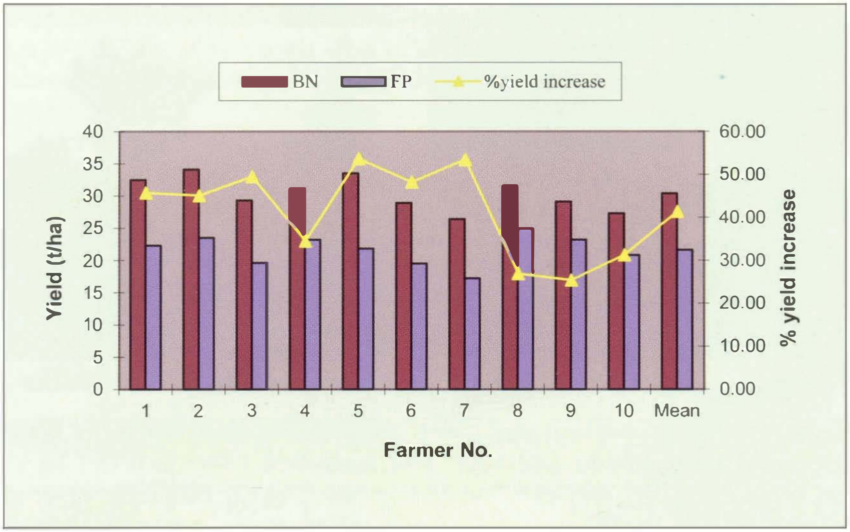


Figure 12. Effects of balanced fertilization on tomato yield in farmers' fields of Dupahad cluster, Nalgonda district, Andhra Pradesh, 2009-2010 (CD (P=0.05) 0.9)

Figure 13. Impacts of SSNM on cotton, mungbean and groundnut in different districts

- **Nalgonda:** In other crops like groundnut and green gram in Dupahad cluster of Nalgonda district, mean seed/pod yield increased from 1.08 to 1.41 t ha^{-1} and from 0.54 t ha^{-1} to 0.75 t ha^{-1}, respectively due to balanced nutrition, registering 31.1 and 39.6% yield increase (Fig.12). Similarly, greengram and groundnut response also varied from 33% to 47% and 18% to 44%, respectively. Among vegetable crops, tomato and bhindi mean yield increased from 21.6 t ha^{-1} to 30.4 t ha^{-1} and 8.7 t ha^{-1} to 11.6 t ha^{-1}, registering 41% and 33% increase in yield, respectively in Nalgonda district (Fig. 13).

- **Warangal:** In Jaffergudem cluster of Warangal, balanced nutrition improved cotton yields significantly in many farmers' fields. In some of the farmer's fields, cotton yields reached to 1.6 t ha^{-1} with balanced nutrition, registering the increase in yields from 5 to 30 per cent over farmers practice.
- **Kadapa:** In Kadapa groundnut yield increased from 0.65 t ha^{-1} to 0.82 t ha^{-1} due to balanced nutrition, registering the yield increase to the extent of 15 to 18% (Fig. 13).
- **Anantapur:** Like in Kadapa, in Anantapur also groundnut yields were increased from 0.67 to 0.88 t ha^{-1} due to balanced nutrition. The response of groundnut to balanced nutrition ranged from 20 to 50%, but generally it was around 25%.
- **Mahabubnagar:** Castor and cotton and *rabi* groundnut responded significantly to micronutrient application. Among crops, response of cotton was the highest (26%) followed by castor (19 %) and groundnut (18%).
- **Rangareddy**: Maize and pigeonpea in light - textured sandy loam soils of Parigi cluster reponded to micro and secondary nutrient application. Maize being an exhaustive crop and soils are deficient in Zn, S, B and Fe, crop response was conspicuous due to nutrient applicaiton to the extent of 15-25 per cent among farmers' fields.

Impact of micro nutrients on farm income

The economic viability of balanced nutrition over the farmers' practice was calculated depending on the prevailing prices of input and output costs. The additional cost (Table 4) incurred in the balanced nutrition as compared to farmers' practice was mainly due to micro and secondary nutrients and additional N and P. Net income and return per rupee investment improved substantially through balanced nutrition (Table 4) (Srinivasarao et al. 2011d).

Table 4. Economic benefits due to Site Specific Nutrient Management and balanced nutrition followed in different crops in target clusters of rainfed tribal dominated districts of Andhra Pradesh

District/Cluster	Crop/No.of trials	Cost of cultivation (Rs./ha)		Net return (Rs./ha)		Return per Rupee investment	
		BN	FP	BN	FP	BN	FP
Adilabad (Seethagondi)	Cotton (14)*	23967	21287	30783-55533 (47174)**	19213-38113 (28540)	2.28-3.32 (2.97)***	1.90-2.79 (2.34)
	Chickpea (14)	11736	9536	5564-14214 (9123)	2228-8110 (5898)	1.47-2.21 (1.78)	1.23-1.85 (1.62)
Khammam (Tummalacheruvu)	Cotton (15)	23967	21287	15033-70533 (49210)	5713-53713 (35828)	1.63-3.94 (3.05)	1.27-3.52 (2.68)

District/Cluster	Crop/No.of trials	Cost of cultivation (Rs./ha)		Net return (Rs./ha)		Return per Rupee investment	
		BN	FP	BN	FP	BN	FP
Nalgonda (Dupahad)	Groundnut (14)	18500	16300	8380-13840 (11068)	2600-8900 (6317)	1.45-1.75 (1.60)	1.16-1.55 (1.39)
	Greengram (12)	12173	9973	4207-8995 (6691)	2375-4895 (3527)	1.35-1.74 (1.55)	1.24-1.49 (1.35)
	Tomato (10)	58074	55874	47526-78326 (63486)	12926-43726 (30526)	1.82-2.35 (2.09)	1.23-1.78 (1.55)
Warangal (Jaffergudem)	Bhendi (10)	39030	36830	15570-38370 (30345)	4570-24370 (15370)	1.40-1.98 (1.78)	1.12-1.66 (1.42)
	Cotton (13)*	23967	21287	9033-22533 (16733)	10213-17713 (13613)	1.38-1.94 (1.70)	1.48-1.83 (1.64)
Kadapa (B. Yerragudi)	Groundnut (13)	9500	7300	2050-11500 (6299)	575-7138(3533)	1.22-2.21(1.66)	1.08-1.98(1.48)
Anantapur (Pampanur)	Groundnut (9)	9500	7300	5200-7300 (6345)	3200-6875 (5205)	1.55-1.77 (1.67)	1.44-1.94 (1.51)

BN= Balanced nutrition, FP= Farmer's practice, *No. of trials, ** & *** Values in parentheses indicate mean values

Adilabad: In cotton, net income obtained varied from Rs. 30780 to 55530 ha^{-1} in Adilabad through balanced nutrition. Similarly, in other crops, net returns obtained was Rs. 5560-14210 ha^{-1} in chickpea in comparison Rs. 19210-38110 ha^{-1} in cotton Rs. 2230-8110 ha^{-1} in chickpea through farmer's practice at Adilabad. Mean value of return per rupee investment was 2.97-3.05 and 1.78 in cotton, chickpea, respectively through balanced nutrition compared to 2.34-2.68 and 1.62, in farmer's practice (Table 4).

Khammam: In cotton, the net income obtained varied from Rs. 15,030 to 70,530 ha^{-1} through balanced nutrition in comparison Rs. 5710-53710 ha^{-1} in cotton at Khammam.

Nalgonda: In Nalgonda net income obtained varied from Rs. 8380 to 13840 ha^{-1} in groundnut, Rs. 4207-8995 ha^{-1} in greengram, Rs. 47530-78330 ha^{-1} in tomato and Rs. 15570-38370 ha^{-1} in Bhendi through balanced nutrition in comparison Rs. 2600-8900 ha^{-1} in groundnut, Rs. 2375-4895 ha^{-1} in greengram, Rs. 12926-43726 ha^{-1} in tomato and Rs. 4570-24370 ha^{-1} in Bhendi through farmer's practice (Table 4). Mean value of return per Re investment was 1.60, 1.55, 2.09 and 1.78 in cotton, chickpea, groundnut, greengram, tomato and Bhendi, respectively through balanced nutrition compared to 1.39, 1.35, 1.55 and 1.42 in farmer's practice.

Warangal: In Warangal, net profit was in the range of Rs. 9033 to 22533 due to balanced nutrition compared to Rs. 10210 to17710 in farmers practice in cotton cultivation. Mean B: C ratio was also improved to the extent of 1.70 due to balanced nutrition (Table 4).

What farmers said!

"Prior to the NAIP project interventions, we applied only diammonium phosphate (DAP) and urea as the sources of nutrients. Over the years, the response to these fertilizers is decreased, with CRIDA soil test based nutrient recommendation including micronutrients, crop yields improved substantially with fertilized."

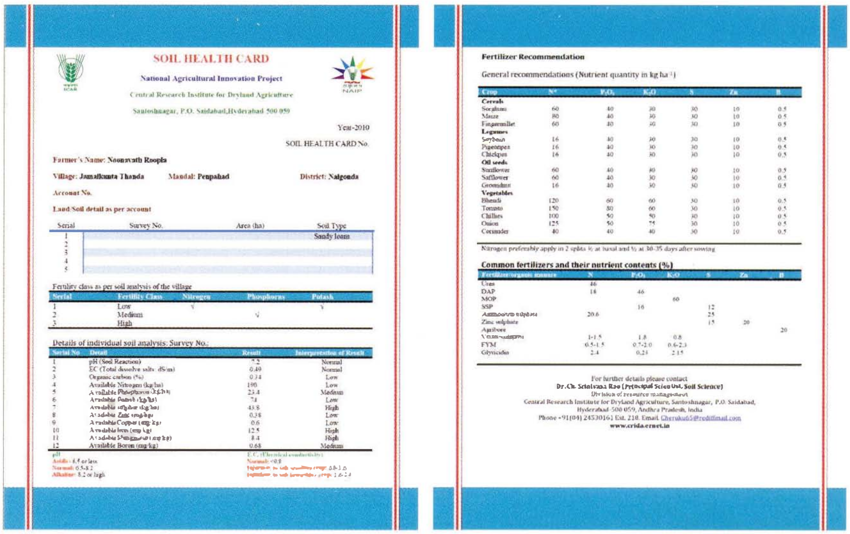
"We apply only DAP and urea and thought that this was good enough for increasing yield. We used to apply manure, but not any more because we don't have enough. So far no one told us about this type of fertilizer. We did not know that small quantities of fertilizers could make such a big difference. We only wish that these fertilizers are easily made available at the right time."

Kadapa: In groundnut, net profit increased to Rs. 6300 due to balanced nutrition in comparison to Rs. 3530 in farmers' practice.

Anantapur: Similarly in Anantapur also, net profit was increased from Rs. 5200 to Rs. 6340 due to balanced nutrition. BC ratio was also improved from 1.51 to 1.67 due to balanced application.

Promotion of soil health cards in the villages

About 1500 farmers were provided soil health cards indicating the identification of the particular farmers' fields, nutrient status, deficiency or sufficiency, and recommendations to different crops and cropping systems (Fig. 14). Soil health cards were made in local language (Telugu) also. Interaction meetings with farmers, field workers and line departments were organized and discussed the importance of soil health cards; soil test based nutrient application and productivity enhancement. The soil test results and various nutrient management practices for location specific crops were loaded in Information Communication Technology (ICT) Kiosk both in English and Telugu in the Village Resource Centre established in 8



SOIL HEALTH CARD

National Agricultural Innovation Project

Central Research Institute for Dryland Agriculture

Santoshnagar, P.O. Saidabad, Hyderabad 500 059

Year-2010

SOIL HEALTH CARD No.

Farmer's Name: Noonavath Roopla

Village: Jamalkunta Thanda Mandal: Penpahad District: Nalgonda

Account No.

Land/Soil detail as per account

Serial	Survey No.	Area (ha)	Soil Type
1			Sandy loam
2			
3			
4			
5			

Fertility class as per soil analysis of the village

Serial	Fertility Class	Nitrogen	Phosphorus	Potash
1	Low	√		√
2	Medium		√	
3	High			

Details of individual soil analysis: Survey No.:

Serial No	Detail	Result	Interpretation of Result
1	pH (Soil Reaction)	7.2	Normal
2	EC (Total dissolve salts: dS/m)	0.49	Normal
3	Organic carbon (%)	0.34	Low
4	Available Nitrogen (kg/ha)	190	Low
5	Available Phosphorus (kg/ha)	23.4	Medium
6	Available Potash (kg/ha)	74	Low
7	Available Sulphur (kg/ha)	43.8	High
8	Available Zinc (mg/kg)	0.38	Low
9	Available Copper (mg/kg)	0.6	Low
10	Available Iron (mg/kg)	12.5	High
11	Available Manganese (mg/kg)	8.4	High
12	Available Boron (mg/kg)	0.68	Medium

pH
Acidic: 6.5 or less
Normal: 6.5-8.2
Alkaline: 8.2 or high

E.C. (Electrical conductivity)
Normal: <0.8
[illegible]: 0.8-1.6
[illegible]: 1.6-2.4

Fertilizer Recommendation

General recommendations (Nutrient quantity in kg ha⁻¹)

Crop	N*	P_2O_5	K_2O	S	Zn	B
Cereals						
Sorghum	60	40	30	30	10	0.5
Maize	80	40	30	30	10	0.5
Fingermillet	60	40	30	30	10	0.5
Legumes						
Soybean	16	40	30	30	10	0.5
Pigeonpea	16	40	30	30	10	0.5
Chickpea	16	40	30	30	10	0.5
Oil seeds						
Sunflower	60	40	30	30	10	0.5
Safflower	60	40	30	30	10	0.5
Groundnut	16	40	30	30	10	0.5
Vegetables						
Bhendi	120	60	60	30	10	0.5
Tomato	150	80	60	30	10	0.5
Chillies	100	50	50	30	10	0.5
Onion	125	50	75	30	10	0.5
Coriander	40	40	40	30	10	0.5

Nitrogen preferably apply in 2 splits ½ at basal and ½ at 30-35 days after sowing

Common fertilizers and their nutrient contents (%)

Fertilizer/organic manure	N	P_2O_5	K_2O	S	Zn	B
Urea	46					
DAP	18	46				
MOP			60			
SSP		16		12		
Ammonium sulphate	20.6			25		
Zinc sulphate				15	20	
Agribore						20
Vermicompost	1-1.5	1.8	0.8			
FYM	0.5-1.5	0.7-2.0	0.6-2.3			
Glyricidia	2.4	0.23	2.15			

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Figure 14. Model soil health cards promoted in the villages

Figure 15. Farmer's awareness on nutrient application in local language Telugu through ICT (left) and training to field workers at CRIDA (right)

clusters of 8 districts (Fig. 15). Farmer can interact with touch screen system and voice based interaction helps in understanding the balanced nutrition and soil test and crop based nutrient recommendations.

Livelihood Impacts of micronutrients

Increasing crop productivity by application of improved technologies was one of the strategies for enhancing the livelihood security of the rural poor in the project. Thus, a systematic effort was made to assess the native nutrient status of soil and supplement the same with application of appropriate nutrients in required quantity. Enhancing crop productivity and household income has been adopted by the project as a short term measure towards improving rural livelihoods. It was observed in many cases in the project area that the additional income generated due to higher productivity and profitability was mostly ploughed back into farming as additional capital. Increased vegetable productivity enhanced cash flow in the family at short intervals. The families that participated in SSNM trials have shown higher consumption of vegetables at the household level leading to better nutritional security as well (Table 5).

Table 5. Impact of SSNM implementation on weekly consumption of vegetables in household (g day^{-1}) in three tribal districts

District	SSNM participant farmer	Check farmer (without SSNM)
Adilabad	350	200
Nalgonda	480	210
Khammam	450	350

*Average family size of 5 members

Many farmers, who realized higher profits due to better nutrient management, used their additional income for improving housing, buying animals, educating children, meeting social obligation, etc. Pelli Venkanna of Jaffergudem says "From the additional profit I got from my cotton SSNM field, I spent Rs. 22000/- to plaster my house with cement," while Korra Harishchandra of the same cluster bought a sheep unit spending Rs. 13500/-. A relatively well to do farmer, Buke Balu invested his profit to fund his son's education (B.Tech).

In Adilabad, D. Ratan of Seethagondi Cluster took up SSNM in chickpea and realized 30% higher income compared to other farmers. He made use of this money for purchasing Bt cotton seeds from a reputed company. He said "like in the previous years, I did not have to compromise with seed quality. Since I had extra money (Rs. 12000/-), I could go for the best in the market."

Though the above anecdotes narrated above give a summary of the livelihood impacts of the SSNM interventions, they do not provide a total picture of all the farmers who adopted SSNM. However, the livelihood impacts which can be diverse and varied can only be captured through anecdotal evidence and qualitative data.

In Dupahad cluster of Nalgonda, the impact of SSNM was observed mainly in vegetables like tomatoes, bhendi, leafy vegetables like palak and flower crops such as marigold. Though these did not translate in large gains like in the case of cotton, nevertheless, the additional income contributed to purchase of household articles, better clothing and additional investment in purchasing better quality inputs for agriculture.

Acknowledgement

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